Nesting habitat of the Little Tern and Fairy Tern at Lake Tyers, Victoria

M Kohout, H Zimmer and V Turner

Arthur Rylah Institute, Department of Environment and Primary Industries,
123 Brown St, Heidelberg, Victoria, 3084

Abstract

This study gathers key baseline data on the vegetation of tern colony sites at Lake Tyers and establishes permanent plots for future monitoring. We characterised the vegetation, substrate type, soil moisture, pH and nutrient levels of Little Tern *Sternula albifrons* and Fairy Tern *S. nereis* colony sites at three islands in Lake Tyers estuary, Victoria. Monitoring plots were established at two colony sites and four non-colony sites, including one abandoned colony site. Vegetation cover was estimated using the point quadrat method. We found that terns nested in areas with 84% ± 1.89 vegetation cover, potentially much higher than reported in previous studies; however, conclusions should be made with caution given the low replication in our study. There was no significant difference in vegetation attributes between colony and non-colony sites. A long-term study including other colony areas along the Victorian coastline would be valuable in understanding colony requirements of these threatened species. This is especially important in the context of the climate change-induced impacts predicted to affect coastal environments in the future. (*The Victorian Naturalist* **130** (5) 2013, 192–201).

Keywords: soil nitrate, vegetation height, seabirds, coastal saltmarsh

Introduction

In Victoria, the Little Tern *Sternula albifrons* and Fairy Tern *S. nereis* are both listed under the *Flora and Fauna Guarantee Act* 1988 as threatened, and are classified as Vulnerable and Endangered, respectively (Reside 2003; Department of Sustainability and Environment 2007, 2009). The Fairy Tern is also listed under the *Environment Protection and Biodiversity Conservation Act* 1999 as Vulnerable. The Victorian distribution of these two species of tern extends along the eastern coastline from Mallacoota to Western Port Bay. In East Gippsland, Little and Fairy Terns are most commonly recorded nesting together on islands in estuaries and occasionally on ocean beaches from Mallacoota to the Gippsland Lakes, though they have also been recorded in far western Victoria (M Weston pers. comm.). For the past five years, the main colony (i.e. breeding) sites used by Little Terns have been in Gippsland: Mallacoota (37°33'0" S, 149°45'0" E), Marlo (37°46'60" S, 148°31'59" E), Tern Island (37°51'5" S, 148°5'29" E), Crescent Island (37°57'4"S, 147°45'31" E) and Corner Inlet (37°45'57" S, 146°20'23" E) (F Bedford and M Bramwell pers. comm.).

Little Terns nest in colonies and nests are typically less than 1.5 m above mean high water (MHW) (Hill 1991). Substrates are usually sandy and the vegetation low and sparse. It is thought that Little Terns avoid nesting in areas with more than 20% vegetation cover, preferring to nest in sparse or scattered vegetation, although this hypothesis has not been rigorously tested (Hill 1991; Owen 1991). Colony sites are created and modified by storms, vegetation encroachment and human activity. The nests of Little and Fairy Terns are typical of those constructed by the Sternidae family, a shallow scrape in the sand, and are often lined with small shells, shell fragments and small pieces of vegetation when available (Reside 2003).

Colony sites in the Gippsland Lakes area have become increasingly important in the maintenance of Little Tern and Fairy Tern populations in south-eastern Australia (Reside 2003). Recent studies, undertaken in the Gippsland Lakes area, suggest Little Tern breeding success is affected by fluctuations in their food source (Taylor and Roe 2004). Why some colony sites have been abandoned remains unknown.

Raven and Plate Islands are the preferred breeding areas in the Lake Tyers estuary and approximately 25 pairs of terns bred at the Lake Tyers estuary in the 2009/2010 breeding season (F Bedford pers. obs.). The two species typically nest together at this location, as they did in the 2009/2010 breeding season. These islands are well vegetated and are periodically inundated.

Considerable variation in plant height and density occurs on the islands, with only small sections used by the terns for breeding. The nearby and larger Tern Island, also well vegetated, is elevated higher above sea level and is inundated only when moderate to severe floods or storm surges occur.

Long-term drought in East Gippsland and artificial opening of the Lake Tyers estuary entrance have caused water levels in the Gippsland Lakes to decrease over the past five years (F Bedford pers. obs.). This has led to concern over potential changes to the Little and Fairy Tern colony sites in Lake Tyers estuary, for example, whether the decrease in water level may impact vegetation on the islands and whether this change would be favourable for nesting or not. Land managers are particularly interested in maintaining Little and Fairy Tern colony sites and, to achieve this aim, colony site characteristics should be quantified.

Our study characterises the physical and vegetative attributes of the colony sites of Little and Fairy Terns at Lake Tyers. Specifically, this study gathers key baseline data on the vegetation of tern colony sites at Lake Tyers and establishes permanent plots for future monitoring.

Methods

Study site

The study area was in the Gippsland Lakes in the Lake Tyers estuary, East Gippsland, Victoria (Fig. 1). The two active colony sites are on Raven and Plate Islands. Raven Island covers 3.5 ha and the colony site area is approximately 50 m × 10 m in size. Plate Island covers 1 ha, with the colony site area covering approximately 60 m × 20 m. Raven and Plate Islands are south of an abandoned (inactive) colony site on Tern Island. Tern Island is larger in size (10 ha) and slightly more elevated. The abandoned colony site examined in this study is situated on the south-eastern tip of Tern Island, where a colony zone (50 m × 50 m) was created from dredge spoil in 1999 (F Bedford pers. comm.).

Vegetation of the islands consists of Coastal Saltmarsh. This Ecological Vegetation Class is restricted to coastal flats subject to the influence of daily inundation and exposure to salt water and poor drainage (Davies *et al.* 2003). Coastal Saltmarsh ranges from a low succulent herbland to shrubland to rushland and sedgeland (Davies *et al.* 2003). Coastal Saltmarsh can comprise several zones. The lowest and most frequently inundated zones are dominated by Beaded Glasswort *Sarcocornia quinqueflora*. The next most landward zone consists of herbs such as: Salt-grass *Distichlis distichophylla*, Creeping Brookweed *Samolus repens*, Shiny Swamp-mat *Selliera radicans*, Rounded Noonflower *Disphyma crassifolium* subsp. *clavellatum* and Southern Sea-heath *Frankenia pauciflora* subsp. *pauciflora*. Sea Rush *Juncus kraussii* subsp. *australiensis* and Chaffy Saw-sedge *Gahnia filum* may dominate the most landward zone (Davies *et al.* 2003).

Sample design

In February 2010, paired sites (colony and non-colony), approximately 80 m apart, were surveyed on each of Plate and Raven Islands. The colony sites have been monitored since 1999 and were designated using visual cues such as nest scrapes and broken eggshell (F Bedford pers. comm.). A single abandoned colony site and a non-colony site were also surveyed on Tern Island. The floristic survey occurred less than 30 days after the Tern breeding season had finished (F Bedford pers. comm.) and no active nests were present. At each colony site, a 6 m × 30 m quadrat representative of the vegetation was positioned parallel to and just above the MHW (Fig. 2). Quadrats in non-colony sites were placed randomly, after stratification according to island, and distance from high-tide mark.

Within the quadrat, three 30 m transect lines were established parallel to the shore line. To enable re-location of the sites, pins and tags were placed at both ends of transects (Fig. 2). The location (easting and northing) of both ends of the centre transect were recorded. Photographs were taken at the four corners of the site, looking towards the centre of the quadrat.

Vegetation cover was estimated for species in the whole quadrat using a modified Braun-Blanquet technique (Mueller-Dombois and Ellenberg 1974) (Table 1). All plant species were identified according to Walsh and Stajsic (2007).

Fine-scale measurements of plant species and substrate (sand, muddy sand, litter, attached litter, driftwood, shell) cover were recorded using

Fig. 1. Location of study site at Lake Tyers and the location of: 1. Tern Island showing the pale coloured abandoned colony site, 2. Raven Island and 3. Plate Island.

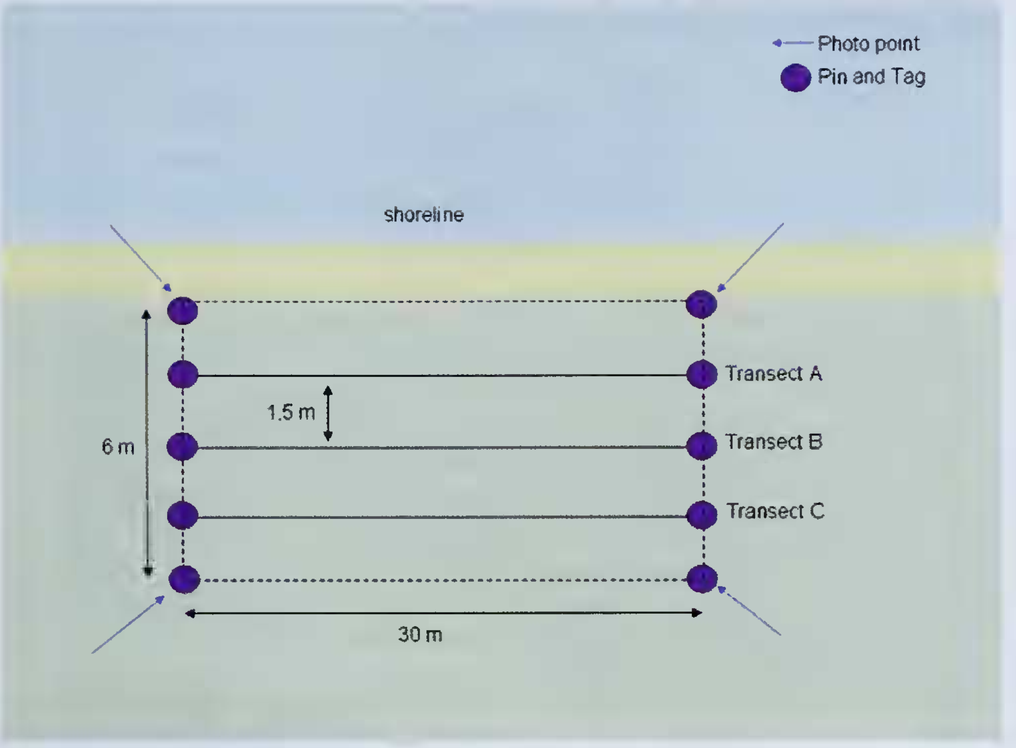

Fig. 2. Schematic diagram of sampling area at each site.

the point quadrat method (Godinez-Alvarez *et al.* 2009) with sampling at 20 cm intervals along each of the three 30 m transects (125 points per transect). This method involves recording the different plant species or substrate that touches a steel pin at given intervals, and since more than one species can touch the pin at each point this can result in a cover abundance of greater than 100% overall. This method is objective and repeatable compared to visual estimates commonly used to estimate cover abundance of vegetation. Furthermore, the precision of cover estimates using the point quadrat method is higher than for visual estimates (Godinez-Alvarez *et al.* 2009). Vegetation height also was measured at 20 cm intervals along the three transect lines using a rising plate meter (Michell 1982). The distance from the edge of the vegetation to the high-tide mark was measured every 1 m along the transect closest to the water.

Three soil samples were taken randomly within each quadrat using an auger. Each sample comprised a core, 0.05 m diameter and 0.1 m depth, incorporating minimal surface litter and avoiding guano. The samples were pooled and a sub-sample was bagged (300–500 g/sample) and subsequently analysed for texture and available phosphorous, total phosphorous, nitrate, ammonium, total nitrogen, potassium, sulphur, organic carbon, total carbon, conductivity, pH ($CaCl_2$), pH (H_2O) and chloride. Analyses were undertaken by CSBP Laboratory (Western Australia). Volumetric soil moisture (expressed as a percentage) was measured within each quadrat, using a theta probe type ML2x (Delta-T Devices, Cambridge, UK) to a depth of 80 mm.

Data Analysis

Plant species data were categorised according to origin, life cycle, and life form. Frequentist statistical analyses were not performed as the potential for significant results was low, given the low replication.

Table 1. Modified Braun-Blanquet cover/abundance scale.

Category	Characters
+	sparsely or very sparsely present; cover very small (< 5%)
1	plentiful but of small cover (< 5%)
2	very numerous, or covering at least 5% of the quadrat area
3	any number of individuals covering 25–50% of the area
4	any number of individuals covering 50–75% of the area
5	covering more than 75% of the area

A principal coordinates analysis (PCO) using the Bray-Curtis dissimilarity index was used to identify differences between the colony and non-colony sites on the basis of (1) plant species and substrate cover and (2) soil characteristics (Legendre and Legendre 1998). PCO was performed using the vegan package in R (Oksanen *et al.* 2011) on data that had been square root transformed and standardised using Wisconsin double transformation (Bray and Curtis 1957; Oksanen *et al.* 2011). PCO was undertaken in R (R Development Core Team 2011). Correlations between dimensions and individual variables were examined using Spearman's rank correlation in R (R Development Core Team 2011).

Results

Vegetation cover and composition

The Little and Fairy Tern colony, non-colony sites and the abandoned colony site were vegetated by coastal saltmarsh. Both colony and non-colony sites were dominated by typical components of coastal, succulent saltmarsh vegetation, namely Creeping Brookweed *Samolus repens*, Narrow-leaf Wilsonia *Wilsonia backhousei* and Beaded Glasswort *Sarcornia quinqueflora*.

The abandoned colony site differed from the other sites in both vegetation and environmental variables. The abandoned colony had the highest cover value of annual species, the lowest cover of perennial species, native tufted graminoids, shrubs and succulents (Table 2). Mean vegetation height was lowest at the abandoned colony site compared to the colony and non-colony sites (Table 2). The vegetation cover of the abandoned colony site was lower (12.8% ± 0.86) than for the colony and non-colony sites (Fig. 3).

Both colony and non-colony sites had a relatively high vegetation cover. The overall mean vegetation cover of colony sites was 84.53% ± 1.89, whilst that of non-colony sites was 96.66% ± 35.32 (Fig. 3).

There was no clear grouping of colony and non-colony sites according to plant species and substrate cover in the PCO (Fig. 4). The first dimension was significantly and positively correlated with Rough Blown-grass *Lachnagrostis scabra* (Spearman's correlation; $\rho = 0.83$, $P = 0.04$). Australian Salt-grass *Distichlis distichophylla* ($\rho = 0.89$, $P = 0.03$) and Knobby Club-sedge *Ficinia nodosa* ($\rho = 0.84$, $P = 0.04$) were significantly correlated with the second dimension. Fifty-nine per cent of the variation between the sites was described by the first and second dimension of the PCO.

Soil attributes

Colony sites had higher nitrates and soil moisture than non-colony sites (Table 3). In terms of soil textural attributes, the colony sites had a higher amount of shell grit than non-colony sites (1% ± 0 and 0.2% ± 0 respectively). The abandoned colony site was characterised by 74% cover of shell grit and had less litter, more bare ground and lower soil moisture than colony or non-colony sites (Table 3).

Eighty-six per cent of the variation between sites, in terms of soil attributes, was described by the first dimension of the PCO (Fig. 5). Variation along this dimension was most significantly negatively correlated with moisture, potassium, conductivity, chloride ($\rho = -1.00$, $P = 0.003$) and clay ($\rho = -0.99$, $P = 0.0003$). There was no clear grouping of colony and non-colony sites according to soil attributes, although the abandoned site was weakly separated on the first dimension.

Discussion

Vegetation attributes of colony sites

At Lake Tyers, Little Tern and Fairy Tern colony sites appear to be characterised by a vegetation cover of 82–85%; however, it should be noted that this is a general observation since there

Table 2. Summary of site vegetation attributes. Data presented are means ± standard deviation for the colony and non-colony site and raw values for the one abandoned colony site.

Vegetation attribute	Colony (n=2)	Non-colony (n=3)	Abandoned (n=1)
Species richness			
Number of plant species	14 ± 1	17 ± 4	13
Species origin			
% exotic	4 ± 5	7 ± 6	23
% native	96 ± 5	93 ± 6	77
Species life cycles			
% annual	22 ± 1	23 ± 6	38
% perennial	74 ± 4	71 ± 4	54
Life forms			
% exotic herb	4 ± 5	7 ± 6	15
% native herb	55 ± 2	59 ± 7	46
% native rhizomatous graminoid	11 ± 5	9 ± 8	15
% native tufted graminoid	15 ± 1	13 ± 4	8
% shrub	15 ± 1	13 ± 4	8
% succulents	56 ± 0	46 ± 20	1
Vegetation height			
Mean height (cm)	5 ± 1	4 ± 2	0.55

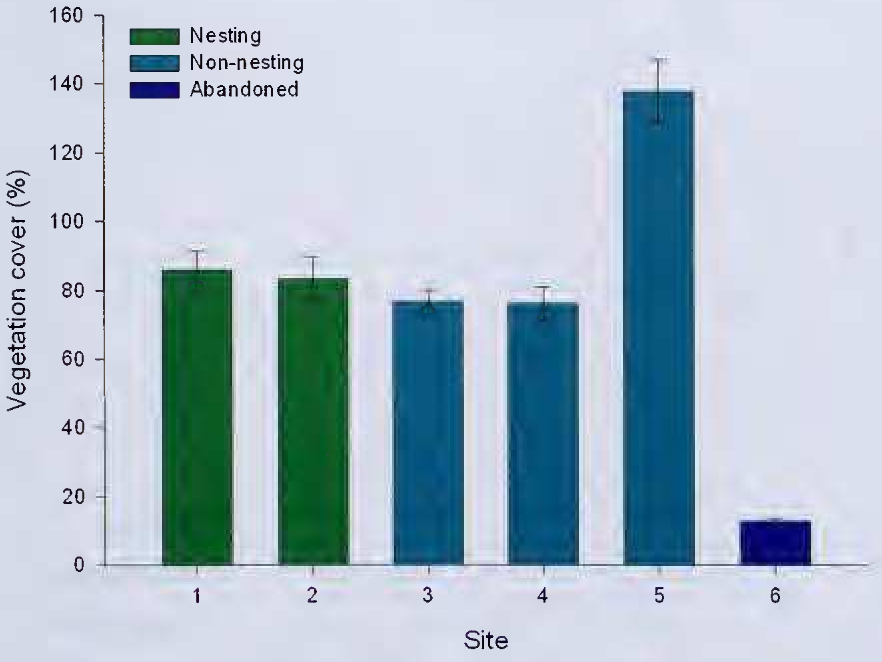

Fig. 3. Vegetation cover (%) across sites. Data are from the point quadrat method and are presented as the mean + standard deviation.

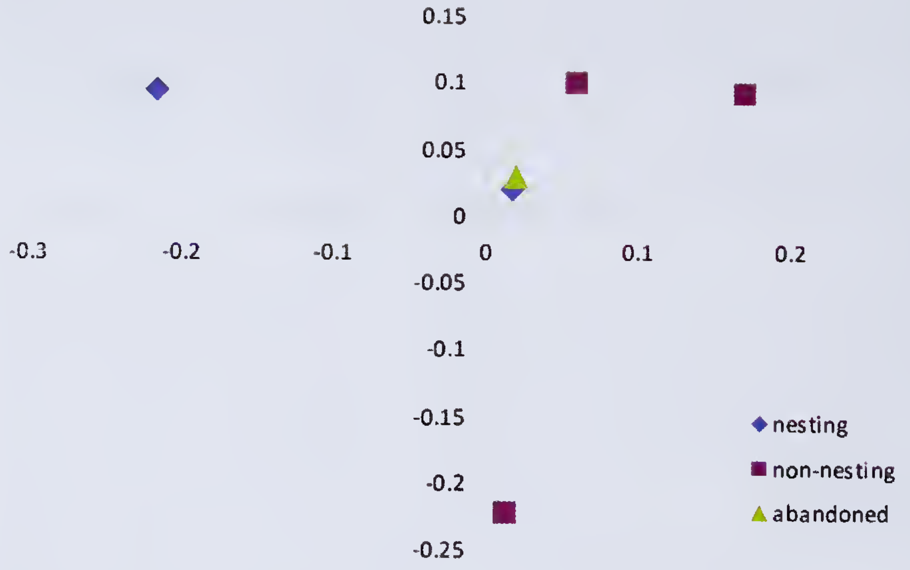

Fig. 4. Principal coordinates analysis plot of mean cover of vegetation and substrate at the tern colony, non-colony and the abandoned tern colony site at Lake Tyers.

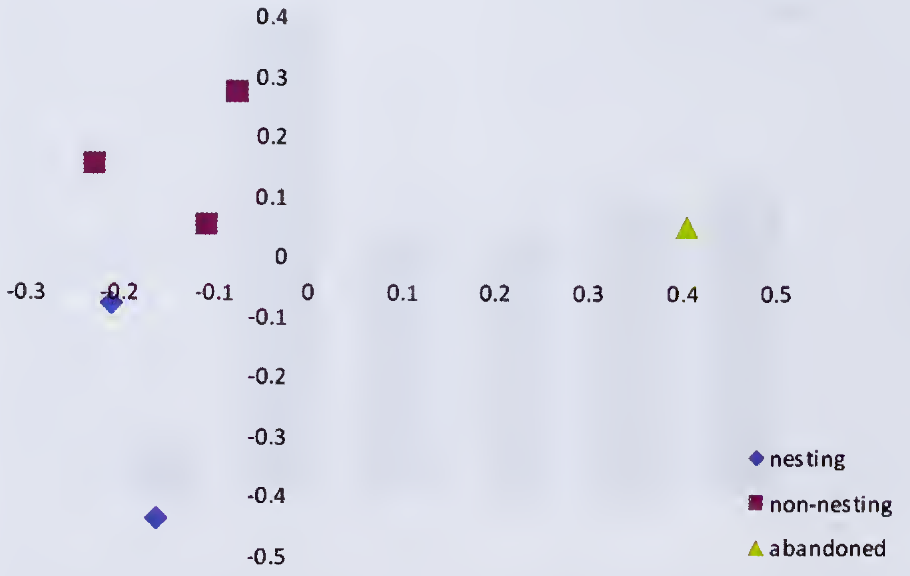

Fig. 5. Principal coordinates analysis plot of soil attributes at tern colony, non-colony and the abandoned colony site at Lake Tyers.

Table 3. Summary of site soil attributes. Data presented are means ± standard deviation for the colony and non-colony site and raw values for the one abandoned colony site. Substrate covers were derived from the point quadrat method.

Site	Colony (*n*=2)	Non-colony (*n*=3)	Abandoned (*n*=1)
Physical attributes			
Mean soil moisture (%)	21 ± 7	17 ± 24	1
Chemical attributes			
Ammonium Nitrogen (mg/Kg)	7 ± 3	4 ± 1	<1
Nitrate Nitrogen (mg/Kg)	6 ± 1	3 ± 1	1
Phosphorus Colwell (mg/Kg)	6 ± 3	3 ± 2	8
Potassium Colwell (mg/Kg)	141 ± 101	258 ± 355	24
Sulphur (mg/Kg)	195 ± 89	456 ± 700	7
Organic carbon (%)	0.3 ± 0	1 ± 1	0.1
Conductivity (dS/m)	2 ± 1	3.8 ± 5	0.1
pH ($CaCl_2$)	7 ± 0	7 ± 1	8
pH (H_20)	8 ± 0	8 ± 1	9
Chloride (mg/Kg)	1389 ± 871	4361 ± 6608	21
Textural attributes			
Clay (%)	5 ± 2	8.1 ± 8	3
Coarse sand (%)	91 ± 4	84 ± 16	94
Fine sand (%)	3 ± 1	3.2 ± 2	2
Sand (%) (sum of fine and coarse)	94 ± 3	87 ± 14	96
Silt (%)	1 ± 1	4.6 ± 5	1
Substrate cover			
Litter (%)	35 ± 2	41 ± 8	0.3
Shell grit (%)	1 ± 0	0.2 ± 0	74
Bare ground (%)	4 ± 4	21 ± 35	74

was a low replication of sites. Nevertheless, this finding is in contrast to previous studies where terns were found to nest in areas where the vegetation cover was less than 20% (Hill 1991; Owen 1991; Department of Sustainability and Environment 2009), and two explanations are possible. It may be that the vegetation cover in previous studies has been underestimated. Alternatively, the terns at Lake Tyers are nesting in suboptimal habitat.

Little and Fairy Terns may choose areas of higher percentage vegetation cover as protection, or perceived protection. The islands in Lake Tyers estuary are frequented by domestic dogs *Canis lupus familiaris*, Red Foxes *Vulpes vulpes*, Silver Gulls *Chroicocephalus novaehollandiae*, Pacific Gulls *Larus pacificus* and Ravens *Corvus* spp. (F Bedford pers. comm). As with other beach-nesting birds, disturbance by predators or humans is likely to influence nesting success of terns (Dowling and Weston 1999; Weston and Elgar 2005). Colony site selection by the Common Tern *Sterna hirundo* is associated with reducing the risk of flooding and accessibility to terrestrial predators (Fasola and Bogliani 1984). These needs are often in conflict, since elevated nest sites are more protected from flooding, but safety from predators requires sites to be at lower elevations since they are less visible (Fasola and Bogliani 1984). Red Foxes sometimes prey upon eggs and young and have caused the abandonment of entire Fairy Tern colonies (Department of Sustainability and Environment 2009). Recreational use of sandy spits and beaches by humans, or even the usage of motorboats nearby, can result in the disturbance of birds from their nests, resulting in chilling or heat stress of eggs and small chicks; trampling of eggs and chicks may also occur (Carney and Sydeman 1999; Dowling and Weston 1999; Weston and Elgar 2005). Such recreational use is common on southern Australian coastlines (Maguire *et al.* 2011).

Less than 20% vegetation cover previously has been reported as being important in tern colony site selection (Hill 1991; Owen 1991). Management of tern colony sites in Victoria has, in some instances, involved vegetation removal such as at Werribee (P Menkhorst pers. comm.), Rigby and Crescent islands (Reside 2003) and the Bairnsdale area (Hill 1991; Owen 1991). As this baseline study suggests that terns may be able to nest in areas with vegetation cover higher than previously thought (82-85% cf. <20%), we suggest that any vegetation removal at tern colony sites should be considered carefully.

A potential explanation for the disparity in estimates of vegetation cover at tern colony sites is survey method. Hill (1991) and Owen (1991) used ocular estimates for vegetation cover. When compared, ocular estimates of vegetation cover are typically lower than objective methods such as point quadrats (Godinez-Alvarez *et al.* 2009). Using ocular estimates for this study we would have reported estimated vegetation covers of 40-60%. However, in this study we used the more accurate and repeatable point quadrat method for collecting cover abundance data, leading to higher cover values (Godinez-Alvarez *et al.* 2009).

Saltmarsh vegetation is zoned according to elevation and inundation, resulting in a strong gradient in vegetation composition and height with distance from the high-tide mark (Bertness and Ellison 1987). Little Tern colony sites tend to be less than 1.5 m above high tide mark (Hill 1991). Sample sites in this study, in colony and non-colony areas, were selected controlling for distance from the high-tide mark. Hence, we were searching for differences between sites that were visually/superficially very similar. An important limitation of this study is the low number of sites surveyed: six sites only, with a maximum replication of three, and these were not independent. Low replication is often a problem in studies of threatened species (see Weston and Elgar 2005); however, this study does provide valuable preliminary data on the characteristics of tern colony sites, and a more extensive survey of the Lake Tyers islands, and of colony and non-colony areas along the Victorian coast, could provide greater insight into tern nest site preferences.

Soil attributes of colony sites

Tern colony sites in the Lake Tyers estuary had higher nitrates than non-colony sites. Previous studies report that seabirds can affect the vegetation of colony sites over time via nutrient inputs, and physical disturbance to soil and plants (Gilham 1959; Vidal *et al.* 2000; García *et al.* 2002). Nitrate and phosphate in seabird guano can result in changes to competitive interactions between plant species (Vidal *et al.* 2000; García *et al.* 2002). In particular, vegetation may move from being dominated by native perennial species, to exotic annual species (Vidal *et al.* 2000). Garcia *et al.* (2002) found that the abundance of two chenopod shrubs was influenced by the amount of gull guano present. The abundance of *Suaeda vera* was found to be higher in guano-rich sites, while *Salsola oppositifolia* was the dominant species in areas least affected by seabirds on Mediterranean islands (García *et al.* 2002). Fairy and Little Terns spend only a few weeks each year breeding at the Lake Tyers estuary islands (F Bedford pers. comm) and their effect on the vegetation may be relatively minor. A longer-term study is required to determine if the vegetation of the tern colony sites is changing, and if this change can be attributed to the terns and their associated nutrient inputs.

Characteristics of a human-made, abandoned colony site

The creation of artificial colony sites is considered a potential conservation action for Little Terns (Hill 1991; Owen 1991). At Lake Tyers, the man-made, now abandoned colony site had vegetation and soil conditions that differed from the colony (and non-colony sites); it had the lowest vegetation cover, the lowest relative cover of native tufted graminoids, shrubs and succulents, and the vegetation was, on average, shorter than at active colony sites. Moreover, it had less litter, more bare ground and lower soil moisture than colony or non-colony sites. In the first years after it was created, the artificial site had more vegetation cover and probably greater soil moisture than at the time of survey (F Bedford pers. comm.). The reasons for these changes are unknown. In terms of management, when creating artificial colony sites, vegetation and soil attributes should be as similar as possible to sites where terns do nest. Although the physical attributes of a site are of importance in selection of colony site, social factors, such as the tendency for birds to return to the same colony site, and social interactions, are also important (Gochfeld 1983).

This study provides key baseline data for the future monitoring of tern colony habitat at Lake Tyers. The methods used in this study were chosen because they are repeatable, and, hence, can be used in a future program of monitoring. We recommend that a longer-term study of tern colonies be undertaken, encompassing more sites from the Victorian coastline. Understanding the colony habitat of these threatened birds is critically important given the changes predicted to affect our coastlines, due to future climate change.

Acknowledgements

The authors wish to thank Mick Bramwell and Faye Bedford for providing detailed background information on Little and Fairy Tern colony ecology at Lake Tyers. In addition, Faye Bedford assisted with fieldwork by showing us sites currently used as colonies. We thank Steve Sinclair, David Cameron and David Cheal for assistance with plant identification, and Peter Smiths for advice on statistical analysis. Claire Moxham, Danny Rogers and Mike Weston helped improve earlier versions of this paper with constructive comments. This work was funded by Department of Environment and Primary Industries (formerly Department of Sustainability and Environment), Statewide Services, East Gippsland. The work was carried out under research permit number 10005735.

References

Bertness MD and Ellison AM (1987) Determinants of pattern in a New England salt marsh plant community. *Ecological Monographs* **57**, 129–147.

Bray JR and Curtis JT (1957) An ordination of upland forest communities of southern Wisconsin. *Ecological Monographs* **27**, 325–349.

Carney KM and Sydeman WJ (1999) A review of human disturbance effects on nesting colonial waterbirds. *Waterbirds: The International Journal of Waterbird Biology* **22**, 68–79.

Davies JB, Oates AM and Trumbull-Ward AV (2003) Ecological Vegetation Class Mapping at 1:25,000 in Gippsland. Department of Natural Resources and Environment, Traralgon.

Department of Sustainability and Environment (2007) Advisory List of Threatened Vertebrate Fauna in Victoria. Department of Sustainability and Environment, East Melbourne.

Department of Sustainability and Environment (2009) Little Tern *Sterna albifrons sinensis*. Action Statement. No. 51. East Melbourne.

Dowling B and Weston MA (1999) Managing a breeding population of the Hooded Plover *Thinornis rubricollis* in a high-use recreational environment. *Bird Conservation International* **9**, 255–270.

Fasola M and Bogliani G (1984) Habitat selection and distribution of nesting Common and Little Terns on the Po River (Italy). *Colonial Waterbirds* **7**, 127–133.

García LV, Maranón T, Ojeda F, Clemente L and Redondo R (2002) Seagull influence on soil properties, chenopod shrub distribution, and leaf nutrient status in semi-arid Mediterranean islands. *Oikos* **98**, 75–86.

Gilham ME (1959) Vegetation of tern and gannet colonies in Northern New Zealand with a comparative note on the colonies in Bass Strait, Tasmania. *Transactions and Proceedings of the Royal Society of New Zealand* **88**, 211–234.

Gochfeld M (1983) Colony site selection by Least Terns: physical attributes of sites. *Colonial Waterbirds* **6**, 205–213.

Godinez-Alvarez H, Herrick JE, Mattocks M, Toledo D and Van Zee J (2009) Comparison of three vegetation monitoring methods: Their relative utility for ecological assessment and monitoring. *Ecological Indicators* **9**, 1001–1008.

Hill R (1991) A strategy for the conservation of the Little Tern in Australia. Australian National Parks and Wildlife Service, Canberra.

Legendre P and Legendre L (1998) *Numerical Ecology*. 2 edn. (Elsevier: New York)

Maguire GS, Miller KK, Weston MA and Young K (2011) Being beside the seaside: beach use and preferences among coastal residents of south-eastern Australia. *Ocean & Coastal Management* **54**, 781–788.

Michell P (1982) Value of a rising-plate meter for estimating herbage mass of grazed perennial ryegrass-white clover swards. *Grass and Forage Science* **37**, 81–87.

Mueller-Dombois D and Ellenberg H (1974) *Aims and Methods of Vegetation Ecology*. (The Blackburn Press: New Jersey)

Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH and Wagner H (2011) vegan: Community Ecology Package. http://CRAN.R-project.org/package=vegan. Accessed 20 February 2012.

Owen R (1991) A report on the management of little terns (*Sterna albifrons*) in the Bairnsdale Region during the 1989/90 breeding season. Department of Conservation and Environment, Bairnsdale, Victoria.

R Development Core Team (2011) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/. Accessed 10 January 2012.

Reside J (2003) Little Tern *Sterna albifrons sinensis*. Action Statement. No. 51. Department of Sustainability and Environment, Melbourne.

Taylor IR and Roe EL (2004) Feeding ecology of little terns *Sterna albifrons sinensis* in south-eastern Australia and the effects of pilchard mass mortality on breeding success and population size. *Marine and Freshwater Research* **55**, 799–808.

Vidal E, Medail F, Tatoni T and Bonnet V (2000) Seabirds drive plant species turnover on small Mediterranean islands at the expense of native taxa. *Oecologia* **122**, 427–434.

Walsh NG and Stajsic V (2007) *A census of the vascular plants of Victoria*. (Royal Botanic Gardens Melbourne: Melbourne)

Weston MA and Elgar MA (2005) Disturbance to brood-rearing Hooded Plover *Thinornis rubricollis*: responses and consequences. *Bird Conservation International* **15**, 193–209.

Received 28 June 2012; accepted 16 May 2013